

Casuarina Coastal Forest Shelterbelts in Hambantota City, Sri Lanka: Assessment of Impacts

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Abstract Growing of *Casuarina equisetifolia* as a small shelterbelt on the beach in Hambantotota City was implemented to protect the beautiful natural sand dunes, preserve visual amenity and be a barrier to seawater salt spray. The casuarina shelterbelt has become popular because it was the only undamaged area in Hambantota City after the devastating 2004 tsunami. The objective of the study was to assess the impacts of the casuarina shelterbelt in economic, social and environmental terms. A survey was conducted to elicit observations and experiences of city dwellers close to the shelterbelt. Respondents did not consider that the shelterbelt reduced wind speed. Although the belt has increased the size of the sand dunes, the casuarina trees have suppressed the growth of native species as an under-storey. The belt has improved the aesthetic value of the beach. No impact of the shelterbelt has been identified in protecting agricultural crops and reducing the corrosion of household goods from seawater salt spray. The city dwellers have not recognized the economic importance of casuarina timber but are impressed with the increase of fuelwood supply from the shelterbelt. The shelterbelt has prevented illegal settlement, but facilitated anti-social and illegal activities among lawless city dwellers. The attractiveness of the beach for tourism has been enhanced. Empirical evidence reveals that the casuarina belt in Hambantota City has greater environmental and social impacts than economic impacts.

Keywords Shifting cultivators · Taungya teak plantation · People participation · Principal components analysis

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Introduction

Casuarina equisetifolia is a popular rapid-growing low-maintenance shelterbelt species, used extensively for windbreaks and coastal stabilization. Casuarina is often planted in sandy soil as windbreaks because of its root suckering habit, extensive foliage which arrests wind velocity, and ability to reclaim soil under excess salinity conditions (Torrey 1976). Although casuarina is not a legume, it does have the potential to form root nodules and fix atmospheric nitrogen (National Research Council 1984). The coastal shelterbelt generally moderates local climate, slowing wind and storm water, cooling and cleaning the air, providing shade, increasing scenic value and enhancing coastal tourism and recreation.

Hambantota City in southern coastal Sri Lanka has an intensely hot arid zone climate with an average annual temperature of 31°C and a 700–1,000 mm annual rainfall (<http://www.weatheronline.co.uk/SriLanka.htm>). Coastal erosion is a severe problem along the Sri Lankan southern coasts including in Hambantota City. As in most of the arid zones, wind erosion is a serious problem in Hambantota. Since the 1980s there has been a growing understanding of the importance of urban shelterbelts to mitigate damage along the coastline (Urban Development Authority 2006). Growing of *Casuarina equisetifolia* as a coastal shelterbelt on the attractive beach in Hambantota City was implemented during 1986–1997 under a forestry development project funded by the Norwegian Agency for Development Cooperation (NORAD). The project has established a stretch averaging 50 m in width and 1 km long from the high tide line covering a part of the city coast. The main aims of the project were to reduce the harmful effect of dry winds and dust storms, protect the beautiful natural sand dunes, and act as a barrier to seawater salt spray.

The casuarina coastal shelterbelt has become a popular focal point for discussion because it was the only area in one of the cities totally destroyed by the devastating tsunami tragedy on 26 December 2004 where casualties and material damage were limited. The coastal shelterbelt along the sand dunes in Hambantota has proven the capacity of coastal vegetation as a ‘soft’ solution for many coastal issues and helped to protect coastal settlements and property from the tsunami (Urban Development Authority 2006). The method of sand dune stabilization was the establishment of vegetative cover a manmade shelterbelt of casuarina trees in Hambantota City coast.

The objective of this study has been to assess the impacts of the casuarina coastal shelterbelt in Hambantota city in economic, social and environmental terms, in the context of promotion of further coastal shelterbelts to mitigate damages while reaping benefits for urban landscapes.

Literature Review

Shelterbelts of trees are recognized to have important benefits in coastal areas. Mitigation of tsunami wave damage through casuarina planting in 2004 was experienced on the Nagapattinam coast of India (Ganesan 2005). Shelterbelt plantations have been established as coastal protection measures in almost all tsunami affected areas in northern part of Japan since 1933 (Edward et al. 2006). Under

normal circumstances, most of the sand removed by storms from beaches in coastal areas accumulates offshore, and moves back to the beach via wave transport. On the beach, casuarina roots retain the sand. Stabilizing of shifting sand dunes is based on the principle of reducing the threshold velocity of wind by the tree-belt. Sand dune stabilization with plant species is more permanent than mechanical mulching and chemical fixation techniques (FAO 1989). Casuarina plantations covering an area of 7,549 ha are serving as a coastal shelterbelt in Tamil Nadu in India, which act as a first line of defence against the effect of frequent cyclonic storms and heavy winds (Institute for Ocean Management 2007). The coastal shelterbelts as acting as a bioshield in the American Midwest Great Lakes provide protection to the households during storms and allow cooling breezes at other times (Wu et al. 2007).

Often sand bars form in front of sea shores, and shelterbelts prevent bare strips on the sand bars due to wind erosion. Sand dunes without vegetation cover move in the direction of the wind, endangering the condition of city households, agricultural crops and roads. To prevent encroachment of beach by tidal waves, the sand dunes must be stabilized. The aims of planting shelterbelt on the Ainsdale sand dunes in the UK were to stabilize the dunes and turn the wasteland into a more productive estate (Simpson and Gee 2004). The development of coastal dunes on the western coast of Hainan Island in China is influenced by forest shelter belts (Sen et al. 2007). Casuarina grown on the Florida coastal dunes have achieved rapid growth, dense shade, and dense litter accumulation. A chemical produced by casuarina inhibits the growth of native plants (IFAS Extension 2007).

The coastal belt is considered as a priority area for re-vegetation under the greening of Kuwait due to the closeness to the main urban and recreational areas which enhance conservation and visual values of this zone (Al Bakri 1994). The 6.67 million ha and a 15,000 km major coastal shelterbelt in China has brought 6.17 million ha of farmland under effective protection and reduced the volume of water and soil erosion by 50% (China Internet Information Center 2002). Coastal shelter belts in Kochi and Miyazaki prefectures in Japan were developed several centuries ago for protecting the agriculture lands from salt spray by strong winds (Edward et al. 2006). Tree shelterbelts act as a wind barrier, which can reduce wind erosion of the soil and increases crop yields by up to 25% (Environment Bay of Plenty 2007). The shelterbelt established on the west coast in New Zealand usually produce at least a commercial crop of logs and firewood (Berg 2006). Torbay Council (2007) in New Zealand under its Regional Planning Guidance for the South West in 2001 noted the importance of coastal landscape planting as groups of trees or shelterbelts belts for tourism. As reported by Vervest (2007), besides providing protection from natural disasters, multiple species shelter belt contribute to local household biomass supplies.

Research Method

This study attempted to identify the major issues associated with the shelterbelt, as input to prepare an integrated coastal management program for Hambantota City. Six officials from the Forest Department and Urban Council of Hambantota directly involved in casuarina planting as a forestry development project were interviewed

informally concerning their views on establishment and maintenance of the casuarina coastal shelterbelt. Personal interviews were conducted of a sample of 50 city dwellers randomly selected from the list of 262 families residing close to the shelterbelt, using a pre-tested questionnaire. The questionnaire was prepared with consideration to the main objectives of the casuarina planting project, and the range of benefits as reported in the literature. Testing of the questionnaire led to addition of questions on corrosion of domestic goods as well as unlawful and anti-social activities. Field observations also added qualitative information, growth of native plants and timber value for the study. The study was conducted in October 2005 and had a 90% response rate of city dwellers for the ultimate sample of 50 respondents.

In the survey of city dwellers, ratings on the condition of each environmental, economic and social issue both before and after the establishment of the shelterbelt were collected using the Likert scale values of: 1 = very low; 2 = low; 3 = moderate; 4 = high; and 5 = very high. Qualitative data were also collected, on a wide range of environmental variables (wind-speed, size of sand dune, growth of native plants, and aesthetic value), economic variables (crop growth, corrosion of domestic goods, timber value, and supply of firewood), and social variables (preventing illegal settlements by landless, tourist attraction, and illegal and anti-social activities associated with the shelterbelt area), which were analysed using the non-parametric sign test.

The responses of the individual city dwellers before and after the establishment of the shelterbelt were counted as n^+ (an increased rating) and n^- (a reduced rating) using the Likert scale. Under the null hypothesis that the shelterbelt does not lead to any change in each of the impact categories, n^+ and n^- are binomially distributed with $p = q = 1/2$ and $n = (n^+) + (n^-)$. The null hypothesis is tested against the alternative hypothesis that the shelterbelt has led to a change, using the test statistic of Z , the standard normal variate, approximated as:

$$Z = \frac{(x + 0.5) - n/2}{\sqrt{n/2}}$$

where n is the number of non-zero differences and x is the number of positive differences (Kanj 1993).

Environmental Impacts of the Shelterbelt

Mean values of the Likert score ranks collected from 50 city dwellers concerning the condition before and after the establishment of the shelterbelt of the each issue categorized under environment, economic and social impacts, and also the Sign test results are presented in Table 1.

Effectiveness of the Shelterbelt in Reducing Wind Speed

In Hambantota City in the semi-arid zone unfavourable conditions of climate and shortage of water are experienced, intensified by strong winds. Planting of casuarina

Table 1 Mean Likert scale rank scores describing city dwellers' opinion before and after the shelterbelt establishment

| Impact category | Before shelterbelt establishment | After shelterbelt establishment | Z statistic from sign test | Probability level |
|---|----------------------------------|---------------------------------|----------------------------|-------------------|
| <i>Environmental impacts</i> | | | | |
| Wind-speed | 3.72 | 3.10 | -0.25 | 0.803 |
| Size of sand dune | 1.86 | 2.58 | 3.83 | 0.000** |
| Growth of native plants | 1.88 | 1.08 | 3.83 | 0.000** |
| Aesthetic value | 2.26 | 3.48 | 2.07 | 0.039* |
| <i>Economic impacts</i> | | | | |
| Crop growth | 2.32 | 2.44 | 1.44 | 0.149 |
| Corrosion of domestic goods | 3.88 | 3.82 | 0.32 | 0.752 |
| Timber value | 1.66 | 1.80 | 1.50 | 0.134 |
| Supply of firewood | 2.14 | 2.82 | 2.25 | 0.024* |
| <i>Social impacts</i> | | | | |
| Prevent illegal settlements by landless | 3.10 | 1.24 | 5.30 | 0.000** |
| Tourist attraction | 3.18 | 4.12 | 2.55 | 0.011* |
| Anti-social activities by unlawful people | 1.94 | 3.28 | 2.77 | 0.006** |

* Significant at the 5% level; ** Significant at the 1% level

in a protective coastal shelterbelt was expected to reduce wind velocity and provide shade in order to improve the living conditions of the city dwellers and agricultural production in the adjoining area. A shelterbelt generally protects an area over a distance up to its own height on the windward side and up to 20 times its height on the leeward side, depending on the strength of the wind (FAO 1989). According to the city dwellers the wind-speed was high (mean score = 3.72) before establishment of the shelterbelt and subsequently has been slightly reduced to a moderate speed (mean score = 3.10) over a distance ranging about 50–400 m from the shelterbelt to where they are residing and with casuarina trees of average 15 m in height. The casuarina shelterbelt has not been able to reduce the wind speed significantly ($Z = 0.250$, $P = 0.803$). It is observed that the residences are close to the shelterbelt but situated at an elevated location relative to the shelterbelt.

Impact on Size of the Sand Dunes

The city dwellers judged that the size of the sand dune which was previously low (mean score = 1.86) has been increased to a moderate level (mean score = 2.58). The casuarina shelterbelt has significantly increased the size of the sand dune ($Z = 3.830$, $P = 0.000$) by an average about one metre as observed by the city dwellers, which was able to prevent damage from the tsunami. It could be observed

that the shelterbelt has grown about 15 m height and lifted the sea wind off the beach creating a large sand dune between sea and trees.

Impact of the Shelterbelt on Native Plant Growth

Salt marshes and dry saline communities are found in the arid extremes of the southeast coasts of Sri Lanka, including Hambantota. The terrain is generally flat with sand dunes bordering the coastline, and vegetation consists mainly of dry thorny scrublands. The semi-arid thorn scrub covers a high proportion of the coastal area providing some ground cover for the soil against excessive loss of moisture. Characteristic species of semi-natural coastal woodlands usually support a rich ground flora. Casuarina in its natural state is gregarious, forming a pure crop with little or no undergrowth except grass and a few coastal shrubs. Generally, the heavy root mat and deep litter layer of the casuarina trees reduce or eliminate competitors (National Research Council 1984). The city dwellers were of the opinion that the casuarina trees have also suppressed the undergrowth, limiting vegetation cover to less plants and biomass, from moderate (mean score = 1.88) to low (mean score = 1.08). According to the city dwellers, the casuarina trees have suppressed the growth of those native species under the canopy within the shelterbelt area ($Z = 3.834$, $P = 0.000$).

Impact on Aesthetic Value

The key concerns relating to the forest landscape characters are the value for recreation and visual amenity. Beautifying the landscape means changing the coastal area from its normal brown colour to a green landscape. One of the main objectives of planting the casuarina shelter belt was to increase the visual amenity of the Hambantota beach. The city dwellers in Hambantota feel that the shelterbelt has improved the aesthetic value ($Z = 2.066$, $P = 0.039$) of the beach from a low level (mean score = 2.26) to a high level (mean score = 3.48). This type of shelterbelt with casuarina trees planted along coastal area has reduced the brown colour and heat of the sandy beach and beautified the urban landscape.

Economic Impacts

Impact of the Shelterbelt on Growth of Agricultural Crops

The lack of vegetative cover exposes the soil to the desiccative effects of hot, dry wind, resulting in dust storms and other forms of severe wind erosion. The growth of many types of agricultural crops is adversely affected by wind through the transport of soil particles and its desiccating effect. Further, the farmers are experiencing salt concentration in the rooting zones of agricultural crops due to the increase of evaporation in irrigated agricultural fields. Generally, such damage can

be reduced by the establishment of shelterbelts. Surprisingly, the urban farmers in Hambantota have not recognized a change in crop growth from the low level before shelterbelt establishment (mean score = 2.32) to after the establishment (mean score = 2.44). The impact of the shelterbelt on their urban and periurban cultivation of agricultural crops established within the distance of about 400 m was non-significant ($Z = 1.443$, $P = 0.149$). The agricultural officials still believe that to control wind erosion and protect agricultural land, establishment of well-designed shelterbelts along the agricultural lands is essential.

Prevention of the Deterioration of Household Goods

Coastal currents transport seawater salt spray along the shore, exposing a much larger area of the residents to its ill effects. The deterioration and corrosion of household goods in Hambantota urban area by seawater salt spray causes substantial economic loss for the city dwellers. Almost all the city dwellers prefer to live as close to the sea edge as possible, but they do not want the sea wind, salt spray and sand blowing into their houses. It is believed that the coastal shelters do moderate strong winds around buildings. However, according to the urban households the casuarina shelterbelt has not reduced the corrosion problem at all, the problem remaining high both before (mean score = 3.88) and after (mean score = 3.82) the shelterbelt was established ($Z = 0.320$, $P = 0.752$). Casuarina has not successfully checked the degradation of household goods mainly caused by the metals arising from salt laden coastal winds. Bushy and sturdy shelterbelts in the city are needed to withstand strong winds to check the degradation of household goods due to salt laden coast winds.

Timber Value of the Casuarina's Shelterbelt

Presently, government attention is focused not only on tree planting but also on increased public awareness of the value of trees and their commercial products. Further, there is a need to expand shelterbelts along the coastal areas to provide timber through fast growing and high-yielding tree species, and to ensure the natural forests are protected. The city dwellers in Hambantota have not recognized the change of the timber value in the area before and after shelterbelt establishment (mean scores of 1.66 and 1.80). They do not recognize any higher value of timber from casuarina trees compared to the native trees which have been grown on the beach ($Z = 1.500$, $P = 0.134$). The choice of species, however, is based on considerations of suitability for the difficult physical conditions on the site. The Forest Department is of the opinion that the best indicator of the most suitable species for an area is the trees already grown there successfully. Casuarina is a salt tolerant and wind resistant species, is adaptable to poor soils and has the ability to fix atmospheric nitrogen. It thrives in close proximity to the sea on loose sand and even grows in close proximity to the high-tide levels. Generally, attempts to saw and season casuarina for use as lumber have not been satisfactory (Loughborough,

unpublished report), and it has little commercial value, although the pulping properties of casuarina have been described as acceptable (Rockwood et al. 1983).

Impact on the Supply of Fuelwood

Forest plantations in arid zones including Hambantota are often proposed for the production of fuelwood, a product crucial for city dwellers. About 38% of respondents in Hambantota rely on fuelwood for their domestic needs because they cannot afford other sources of energy. If fuelwood is scarce, more time must be spent in fuel gathering from distant sources at the expense of productive work. The coastal shelterbelt also provides the city dwellers with trees that could be cut for fuel and fencing material. The residents of this poor city have been impressed with the increase in fuelwood supply from the casuarina shelterbelt, with a mean Likert score increasing from low to moderate (2.14–2.82) level ($Z = 2.250$, $P = 0.024$). Cutting of shelterbelt trees to obtain firewood is prohibited, although collecting fallen twigs from the forest floor is allowed. Casuarina trees are well suited for fuelwood because of their high growth rate and coppicing potential. Although casuarina wood has a high density, the green wood moisture content is relatively low, making the energy value considerably higher than that of other species (Rockwood et al. 1983), and casuarina wood dries rapidly and burns well.

Social Impacts

Impact on Prevention of Illegal Settlements

Planning of coastal shelterbelts in cities needs to take into account the existing settlement patterns, land uses, livelihood needs and structures, and environmental sustainability issues within the urban centre. The conflicts over competing interests for use of the land have to be reconciled. It is common in many Sri Lankan cities that the urban poor have obtained access to land through informal settlements in fringe areas and even hazardous lands. The illegal settlements on the coast of Hambantotata City could have resulted in rapid deterioration of the coastal environment with untreated waste, erosion and uncontrolled access to the natural resources. The government authorities in Hambantota City, together with the Forest Department, have taken the responsibility for protecting coastal areas from irreparable environmental and social consequences. The casuarina tree belt has successfully prevented illegal settlement from a moderate level (mean score = 3.10) to very low level (mean score = 1.24), the change being statistically significant ($Z = 5.295$, $P = 0.000$). Illegal settlements are put up on the city's beach by the poor city dwellers, particularly the fishermen. It is still not possible to forecast accurately tsunamis and tidal storm disasters. The building of the coastal shelterbelt in Hambantota City and also keeping settlements away from the coastline are vital to mitigate both environment and storm damage. It is believed that the coastal shelterbelts absorb the force of waves from a tsunami or typhoon before they

can reach inhabited areas close to the shore. After the devastating tsunami the national government declared a 50 m wide coastal conservation buffer zone to protect the coastal population and the environment.

Impact on Attractiveness for Tourism

Coastal beaches are considered as one of the most popular tourist attractions in Sri Lanka. Tourism in Hambantota City has been recognised as an industry with great potential for further economic development. The Forest Department has initiated the promotion of ecotourism because of the dynamic tourism industry in the city. Both the Forest Department and forestry development project of the Integrated Rural Development Project of Hambantota were involved in the establishment of the casuarina coastal shelterbelt. The city dwellers have recognized that the casuarina shelterbelt has enhanced the attractiveness of the city beach as a tourist destination, mainly due to provision of shade, from moderate (mean score = 3.18) to high (mean score = 4.12), which represents a significant change ($Z = 2.550$, $P = 0.011$). The public has become increasingly interested in nature tourism, and appreciation of the landscape and the environment in general is growing. Sri Lanka declared the year 2000 as the 'Year of Ecotourism', in recognition of this fast growing segment in the tourism sector. The casuarina shelterbelt has also increased the comfort of travellers on the main road on their way to the highly respected religious destination of Kataragama, by providing shade and attractive surroundings. The environment of the seafront has been improved, with shelter and amenities as well as access to car parks.

Impact on Prevalence of Anti-social Activities

The accessibility of woodlands and natural spaces has implications for crime and safety issues. Instead of enjoying the spaces available to them, unfortunately the shelterbelt provides cover for many anti-social and illegal activities by lawless city dwellers. Although the previous anti-social activities in Hambantota City were considered as relatively low (mean score = 1.94), the shelterbelt has increased many activities presently to a moderate (mean score = 3.28) level ($Z = 2.772$, $P = 0.006$). The anti-social activities by the city dwellers which are of direct concern are the incidents of arson, car break-ins, illegal alcohol and drug sales, and theft. These anti-social activities together with a fear of crime have a considerable impact on the urban communities. Respondents expressed concern that the shelterbelt made the beach a potentially threatening place at night, dangerous to walk along and creating many blind spots behind the trees.

Conclusions and Policy Implications

Contrary to expectations, the coastal shelterbelt in Hambantota City appears not to have reduced the speed of salt-laden winds blowing through the area closer to the shelterbelt, and has had the negative impact of suppressing native plant growth

under the casuarina trees. The increase in the size of sand dunes and the provision of aesthetic and micro-climatic benefits to the beach are considered the main positive environmental impacts. The casuarina shelterbelt is not able to act as a windbreak for adjacent agricultural fields, to reduce the corrosion of household goods by salt laden wind, nor even to produce timber with economic value for the area. However, the shelterbelt provides city dwellers living close to the shelterbelt with fuelwood, saving both money and time spent on fuelwood collection. Prevention of illegal settlement by the poor and creating attractive surroundings for tourists on the beach of the city are important social impacts of the shelterbelt. The increase of illegal activities within the shelterbelt has created some social concern among the city dwellers.

It is expected that shelterbelts will be established in other coastal cities, given the favourable results already achieved on the Hambantota City coast. The coastal shelterbelts may be designed and established by the Forest Department and City Council together with the Coastal Conservation Department as a joint effort relevant to each institute and in consultation with the city dwellers. Ideally, the shelterbelts will be designed as bushy and sturdy structures with tree species of economic, social and environmental importance, and maintained to ensure the positive impacts and to reduce real and perceived dangers. A national tourism policy focusing on ecotourism with a potential component of integrated coastal zone management is required by the residents of the coastal zones, city councils and the Tourist Board, in order to increase the benefits from coastal shelterbelts.

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